CGG 3D Surface-Related Multiple Modelling: A Unique Approach

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Abstract

Summary

Marine seismic data acquired over seafloors with rough topography are characterized by the presence of complicated multiple energy patterns. Data-driven SRME (Surface Related Multiple Elimination) techniques do not require any *a priori* knowledge of the subsurface (reflectivity, structures and velocities). However, these methods require a shot location at each receiver location, wherein lies the main difficulty for their 3D implementation. Today, solutions involve reconstruction of the missing data or reconstruction of the missing multiple contributions. In the following, a model-based surface-related multiple modelling (SRMM) technique is presented free from any constraint relating to the shot position and distribution. This technique may require streamer interpolation/extrapolation, but does not require any sail lines reconstructions. An offshore Brazil example demonstrates the efficiency of our 3D SRMM approach to handle complex diffracted multiples due to the 3D structure of the water bottom. 3D surveys acquired in Offshore East Coast Canada from the continental shelf to the sub-basins have and will benefit from the update of our technology in the 3D demultiple domain.

Introduction

Multiple generation "squares" (at least for first order multiples) the degree of complexity of the reverberated reflected energy, and, in general, there is no domain, neither time, depth, nor pre or post migrated, where multiples and primaries can be simplified simultaneously. Conventional separation methods based on multiple periodicity or residual move-out will fail, and it is therefore necessary to predict deterministically the multiples in 3D to ensure proper denoising of the seismic data.

Data-driven SRME techniques ideally require one shot location for each receiver position, and this is not the case for most 3D acquisition geometries. The first solution to this problem requires the use of existing data only, and then extrapolation of the available multiple contributions. The second solution requires interpolation of the input data, thus creating the missing streamers and shot lines for the required convolutional process. Model-based modeling techniques may require interpolation between streamers, but not between sources.

Technical overview

The surface-related multiple modelling technique presented by Pica et al. (2005) consists in using the pre-stack demigration of a migrated volume and subsequently simulating the reverberations of primary energy within this volume. It assumes that the migrated section is a reliable representation of the actual subsurface reflectivity. By comparison, SRME convolution of the data with the primaries (Vershuur and Berkhout, 1997, Biersteker, 2001) immediately provides all order multiples with the right kinematics, while in the first stage of the model-based SRME, the demigration leads to the primaries model. The second iteration consists in reintroducing previous primaries as sources for a new modelling, thus leading to the first-order multiples. These correspond to the second term of the Neumann series, and more iterations lead to higher order multiples. It is possible to skip this cyclic procedure if the deconvolved and regularized shot records are available. The regularization is done by interpolation between streamers using RNMO or FX type interpolation. In this case, the shot record can be used as an areal source in the modelling procedure (Figure 1). As long as the primary modelling into a multiple-free migrated section is reliable, then:

$$(1) \qquad M = s^{-1} * D * P \ .$$

where D are the data, P the primaries and M the modelled multiples. The symbol `*´ stands for a multidimensional surface-consistent convolution operator, and, s^{-1} the inverse wavelet or wavelets. The alternative technique using regularized shot records as an areal source for the demigration procedure tends to be more robust when dealing with water period peg-legs of shallow events in addition to the direct sea-floor multiples. The input for the demigration procedure consists of a migrated section; time or depth, a velocity macro-model and the data trace coordinates for the shot record in question. The ringing of the primaries and multiples through the target volume is modelled using the one-way wave equation. The method therefore handles well the problems of cable feathering, as there is a propagated wave field all along the acquisition surface. The OBC case geometry is also easily handled as the sources (common receiver) can be placed anywhere. The need for a migrated section might be seen as an obstacle, but nowadays with the massive PC clusters, even pre-stack time migrations are produced with a short turnaround. The sharpness of the migrated image will be critical in determining the capability to generate diffractions in the modelling, but conventional migration illumination sizes allow for good definition of subsurface details. As the process is run per shot record there are little data transfer flows, which makes the technique well suited to parallel implementation on PC clusters.

Data example

Experience of the application of our 3D SRME to real data includes cases from Gulf Of Mexico, North Sea, offshore Angola, offshore Brazil and Offshore East Coast of Canada. Our Offshore Brazil data example illustrates the benefits of this technique for modeling multiples in 3D from the complex seafloor and its neighboring reflectors. A crossline section from the migrated seismic block shown in Figure 2 illustrates the complexity and roughness of the sea floor. It is a submarine canyon environment where the bathymetry varies from 200 to 2000 meters depth inline and generates complicated multiple patterns which are not well attenuated by conventional 2D demultiple techniques.

Due to the reduced extension of the main multiple generator, consisting of the sea bottom and close reflectors, a constant velocity macromodel was used for the wavefield propagation. Second order multiples were included in the modelling since the constant velocity assumption and the limited thickness of the generators allowed a reasonable cost to be maintained at the modelling stage. As a consequence of the rugose sea floor, the multiple contamination is severe and complex on the initial stack section (Figure 3a). A conventional 2D SRME have been applied and shown improvement in some spots of the section but failed when the modeling of the sea bottom and close reflectors required 3D assumptions (see red arrows locations on Figure 3b). The multiple model obtained by our pre-stack 3D SRMM, within the constant velocity assumption, identifies the complexity of the seafloor and sub-surface events. After a pre-stack adaptation and subtraction of the model of the multiples via a least-squares multi-channel approach, a cleaner section is obtained which is superior to the section produced after the conventional 2D SRME approach (see red arrows on Figure 3c).

Conclusions

The input to the model-based surface-related 3D multiple prediction consist of a migrated section, a velocity macro model and the shot point(s) for which the multiple model is required. The strengths of the method are that it runs shot per shot, which requires little data transfer, and it does not require a shot location for each receiver position, which makes it independent of the acquisition geometry. It handles cable feathering and can process OBC acquisition geometries as well. The benefit of the 3D SRMM is demonstrated on this Offshore Brazil example to handle complex diffracted multiples due to the 3D structure of the seafloor and complex sub-surface events.

References

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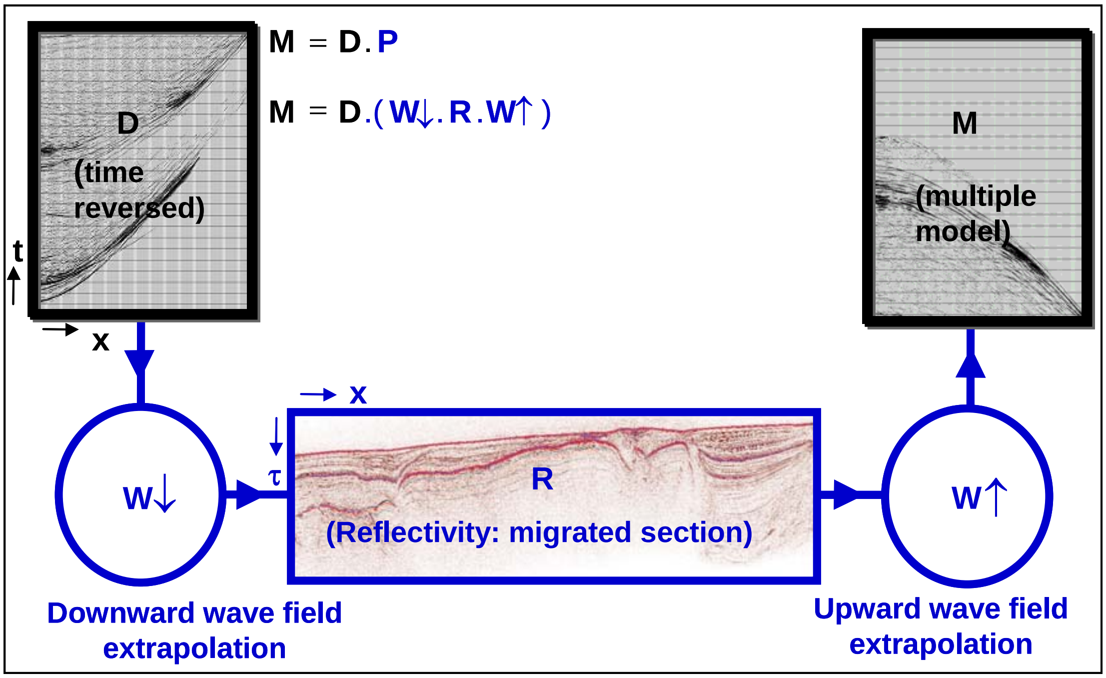

Figure 1. Principles of the model-based surface related multiple prediction using regularized shot records as an areal source for the demigration procedure.

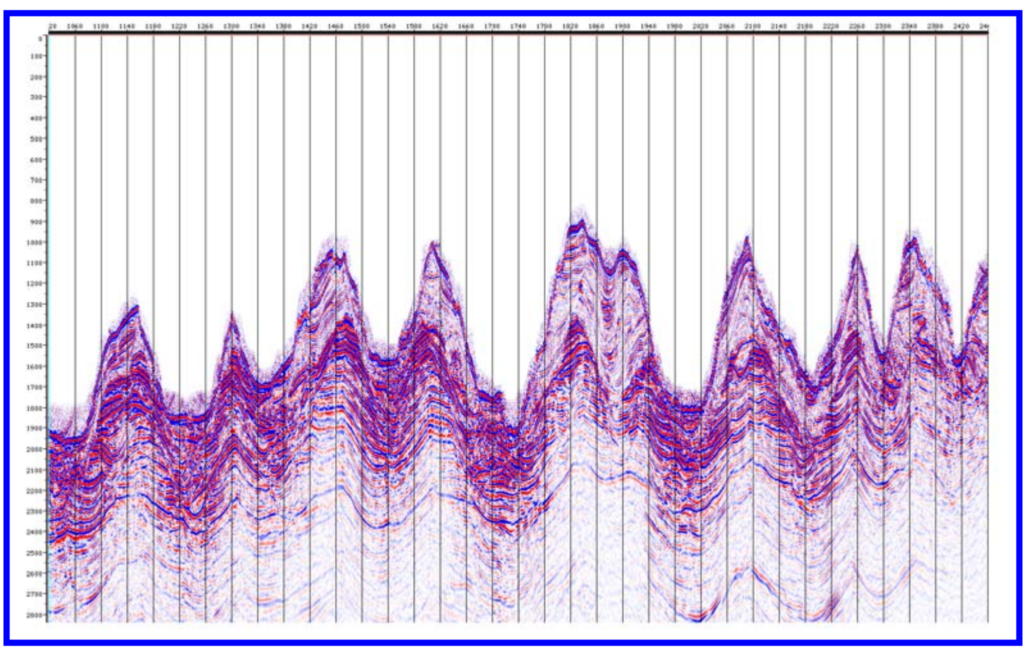

Figure 2. This crossline section from the migrated seismic block illustrates the complexity and roughness of the sea floor from this Brazilian dataset processed with 3D SRMM. It is a submarine canyon environment where the bathymetry varies from 200 to 2000 meter depth inline.

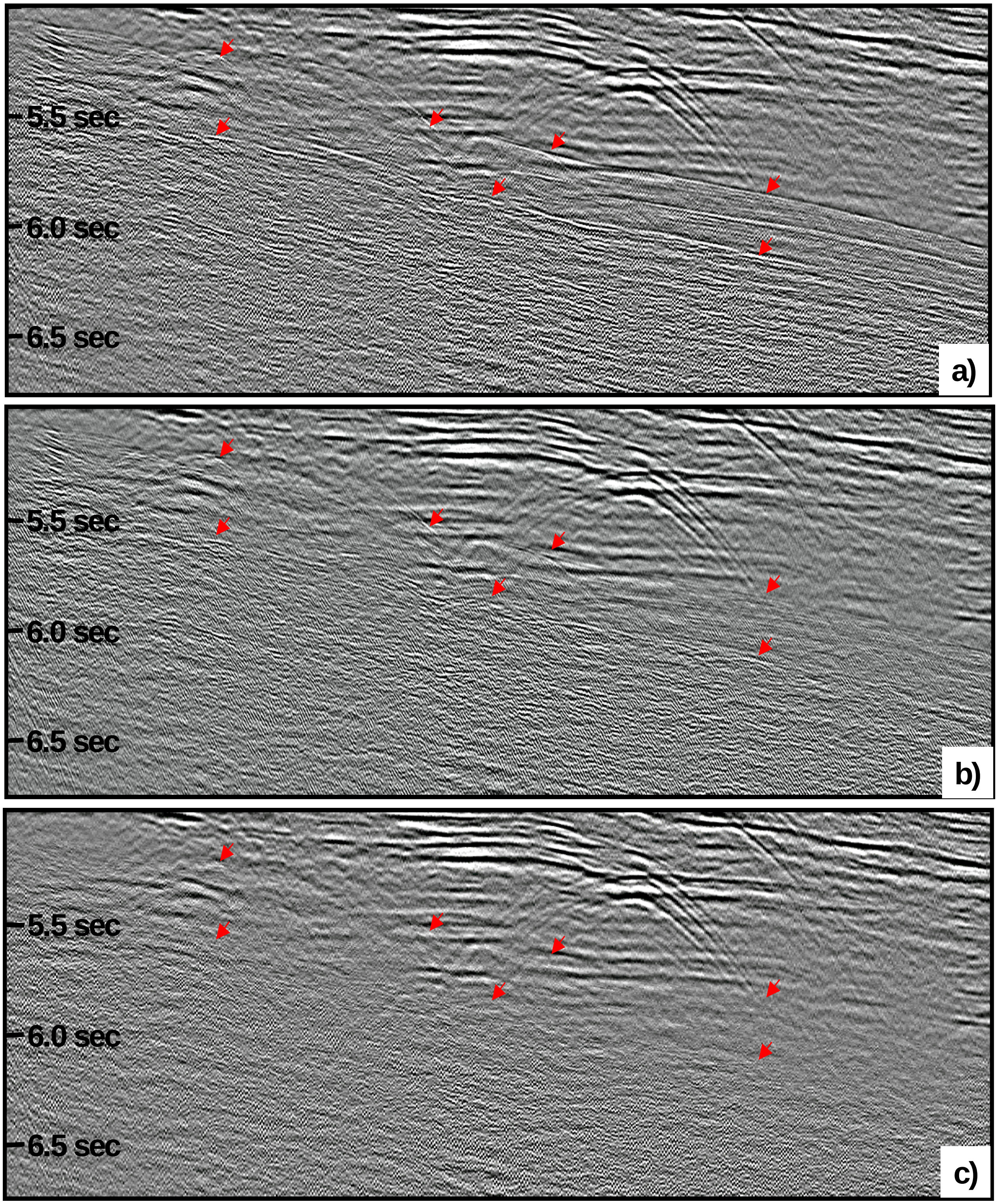

Figure 3. Stacks of the central subsurface line after least-squares multi-channel pre-stack adaptation and subtraction. a) No demultiple. b) 2D SRME. c) 3D SRMM